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~~ARCADIS Project No.:~~
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Subject:
Evidence ~~for~~ of an Off-Site Source of TCE, 1,1-DCE, and Total Chromium in the Regional Aquifer under the HELSTF

The Phase III investigation~~s~~ activities at the High Energy Laser Systems Test Facility (HELSTF) produced data that revealed a separate uncharacterized source of groundwater contamination located upgradient (northwest) of the HELSTF. Since this ~~did not become~~was not evident until after field activities were completed, the following analysis was performed to determine if the off-site source could be well enough understood to relate or disassociate it, as appropriate, from potential HELSTF sources.

The contaminants related to ~~the~~ an off-site source form a plume that extends from the source area to beneath the HELSTF and it is their combination, distribution, and temporal concentration trends that suggest a separate upgradient source. The regional aquifer wells that appear to have been directly affected by this source include HMW-61, DRW-16, and DRW-14 (Figures I-1, I-2, and I-3). They are located 1,000 feet upgradient of the HELSTF boundary, near the upgradient limit of HELSTF activities, and just downgradient of the center of HELSTF activities, respectively.

Combination of Chemical of Potential Concerns (COPCs) Present

Groundwater recovered at HMW-61, DRW-16, and DRW-14 exhibits a unique contaminant signature, containing trichloroethylene (TCE) near 100 micrograms per liter (µg/L), total chromium over 500 µg/L, and 1,1-DCE in the 10 µg/L range (Figures I-1, I-2, and I-3). There are no other wells in either the vadose zone or regional aquifer that exhibit this combination of contaminant concentrations. In the current data set 1,1-dichloroethene (1,1-DCE) is almost uniquely detected in these wells. As of 2009, only three wells in the vadose zone slightly exceeded the groundwater standard of 5 µg/L ~~in the vadose zone~~ (Figure ~~6.25.6-2~~I-1), however, there is no evident source at the HELSTF[CED1][KH2].

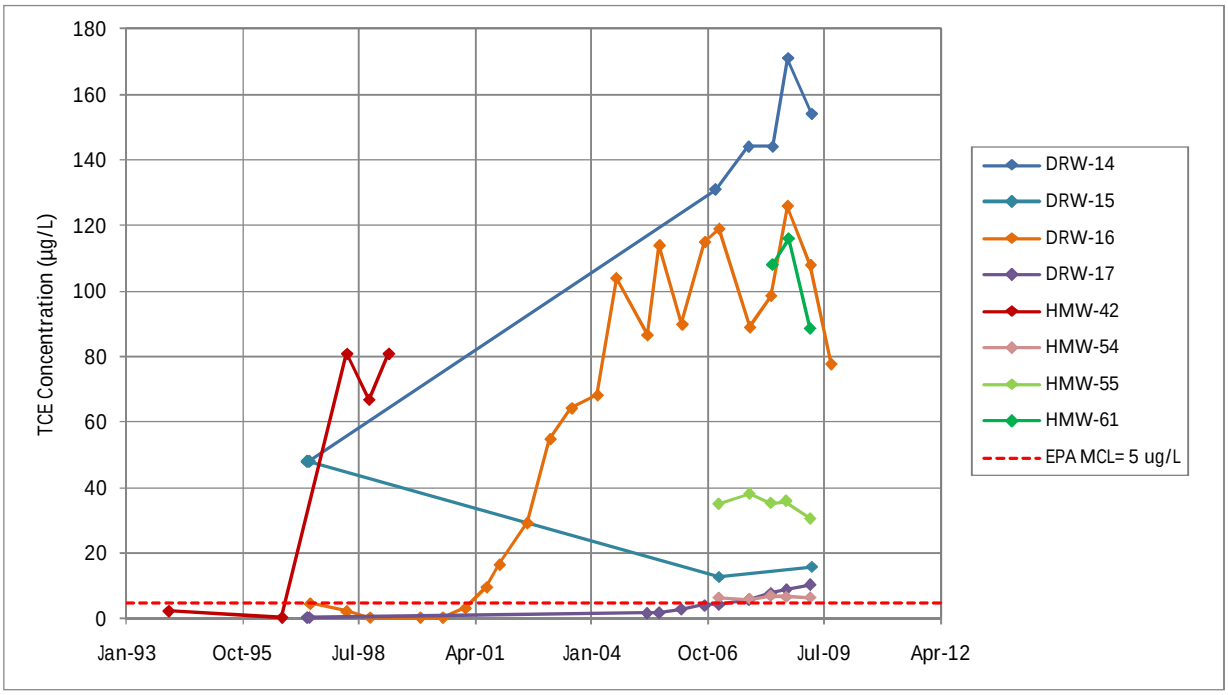
Chromium concentrations in DRW-16 and DRW-14 far exceed concentrations detected in vadose zone groundwater anywhere at the HELSTF, indicating that there is no realistic surface or near-surface source at the HELSTF. Even the known release of chromate waste at SWMU 143 has not resulted in the magnitude of concentrations observed in the Regional Aquifer. For example, it appears to have produced only a very small affected area in the vadose zone with nearby vadose zone water concentrations at HMW-41 that are much less than those detected at Regional DRW-14.

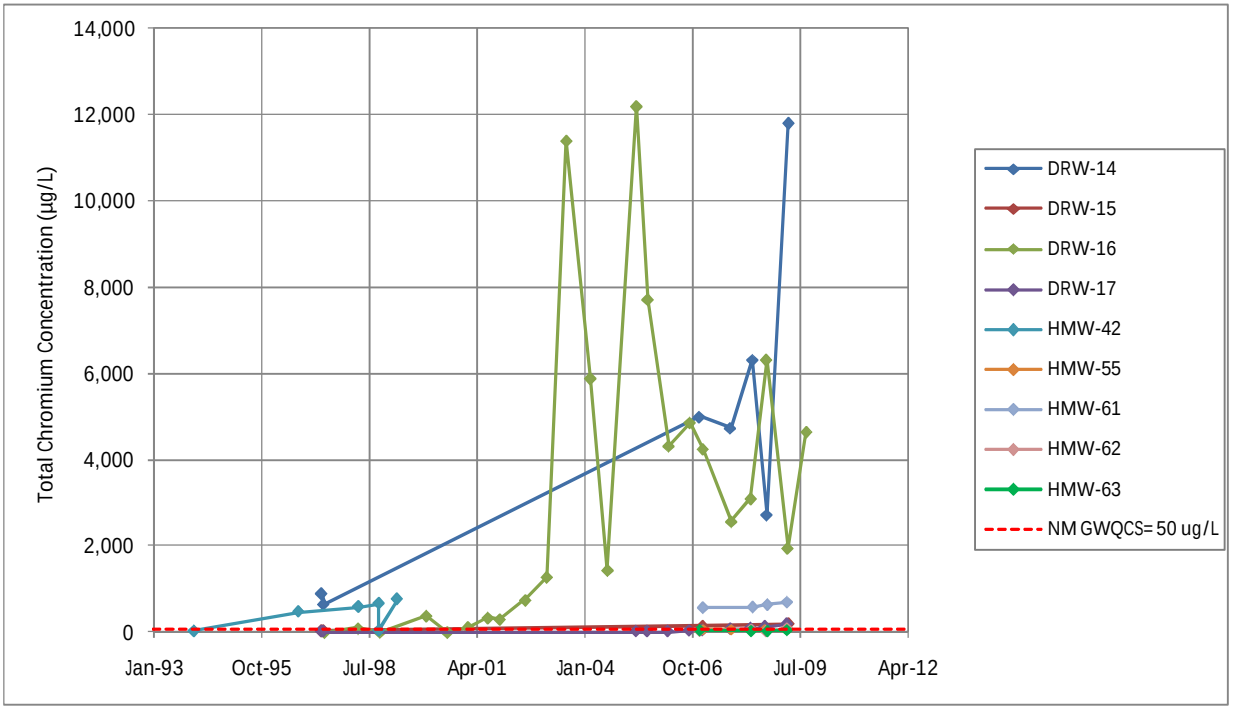
Distribution of COPCs

Several additional factors support that a source outside of the HELSTF area has resulted in impacts of chromium and TCE at HWM-61, DRW-14, DRW-16, and other Regional aquifer wells~~.F~~. When the concentrations of TCE and total chromium are mapped in the regional aquifer, they occur in three wells along a pathline consistent with the direction of groundwater flow from HWM-61. The most upgradient well installed in the regional aquifer within the HELSTF boundary (DRW-16) is more strongly impacted by both TCE and total chromium than nearly all of the wells installed in the central and downgradient part of the HELSTF with the exception of the two wells (DRW-16 and DRW-14, located directly downgradient). There are no vadose zone wells between the possible HELSTF source(s) of COPCs and this upgradient source in the regional aquifer that show evidence of the transport of water of this composition to the northwest. transported

Temporal TCE and Total Chromium Concentration Trends

Evaluation of changes in concentration over time for both TCE and total chromium was completed for many ~~monitor well~~monitoring wells in the regional aquifer. Results clearly indicate that there was breakthrough of upgradient impacted groundwater reaching these wells. The most upgradient well of the HELSTF area (DRW-16) has been sampled and analyzed for TCE and total chromium since May 1997. The concentration of both contaminants increased significantly (and coincidently) between 2000 and 2004. Graphs showing concentrations over time are presented below.


TCE Concentration (µg/L)
180
160
140
120
100
80
60
40
20
0
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
Oct-06
Jul-09
Apr-12
DRW-14
DRW-15
DRW-16
DRW-17
HMW-42
HMW-54
HMW-55
HMW-61
EPA MCL= 5 ug/L


Total Chromium Concentration (µg/L)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Jan-93
Oct-95
Jul-98
Apr-01
Jan-04
Oct-06
Jul-09
Apr-12
DRW-14
DRW-15
DRW-16
DRW-17
HMW-42
HMW-55
HMW-61
HMW-62
HMW-63
NM GWQCS= 50 ug/L

Breakthrough of both TCE and total chromium, as defined by half the maximum observed concentration, occurred in January 2003 at DRW-16. The total chromium concentration was reported as 1,280 µg/L in January 2003 and reached a maximum concentration of 11,400 µg/L in July 2003 (this maximum total chromium concentration is higher than any historically measured concentrations in the vadose zone beneath the HELSTF). Thus, upgradient impacts clearly reached this area in January 2003.

A similar breakthrough pattern can be observed at ~~Monitor Well~~m~~M~~onitoring ~~w~~Well DRW-17. The observed concentrations are lower at this location compared to DRW-16, indicating that DRW-17 is located on the edge of the total chromium and TCE plume. Breakthrough occurs later at the plume edge than at the center. The increase of TCE and total chromium coincide and occurred in the beginning of 2006.

Increasing contaminant concentrations have also been observed in ~~Monitor Well~~m~~M~~onitoring ~~w~~Wells DRW-14 and DRW-15, which are located directly downgradient of DRW-16. HMW-55 was not sampled prior to January 2007 and no significant changes in total chromium or TCE concentrations have been observed since that time. The TCE and total chromium concentration at DRW-14 and DRW-15 increased significantly between May 1997 and December 2006; however, no samples were collected over this 9-year period and the exact timing of the breakthrough cannot be determined. Clearly, however, upgradient impacts reached this area after 1997 and before 2007.

Because the upgradient Well HMW-61 was installed in 2008, historical concentrations in this area are not known. However, if contaminant arrived at this well due to an upgradient source in 1999 and the average contaminant transport velocity was approximately 300 feet per year, the expected average arrival date at the wells most directly down gradient would be 2003 for HMW-16 and 2006 for HMW-14. These expected arrival times match up exceptionally well with the actual arrival times at these wells; this further supports that the observed total chromium and TCE impacts at these wells are largely due to off-site sources.

Transport Modeling

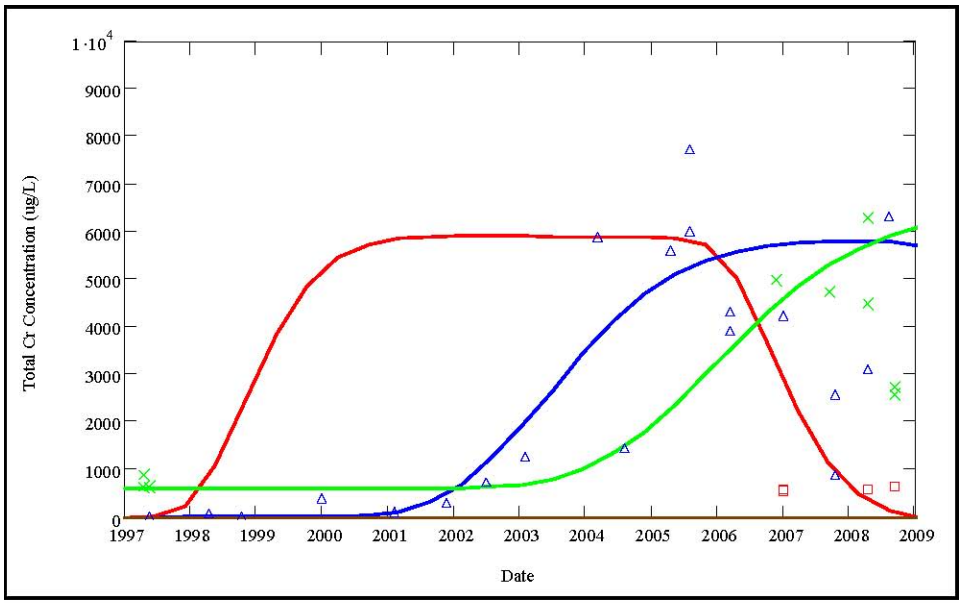
A one-dimensional solute transport model (van Genuchten et al. 1989; and Toride et al. 1993) was used to further evaluate the temporal TCE and total chromium concentration trends. The model used includes relatively simple assumptions (e.g., uniform aquifer properties, steady hydraulic conditions); however, it does represent the characteristic “dual domain” transport behavior expected for the site by accounting for advective transport in the more permeable coarse-grained channel form features with diffusive mass transfer to and from the less permeable silts and clays. Quantitative site data do not exist to directly support parameter values; therefore, parameter values were adjusted or calibrated to obtain simulated results that best match actual data. However, the final parameter values used are shown in the table below are within ranges considered appropriate for the site based on qualitative site data and professional experience.

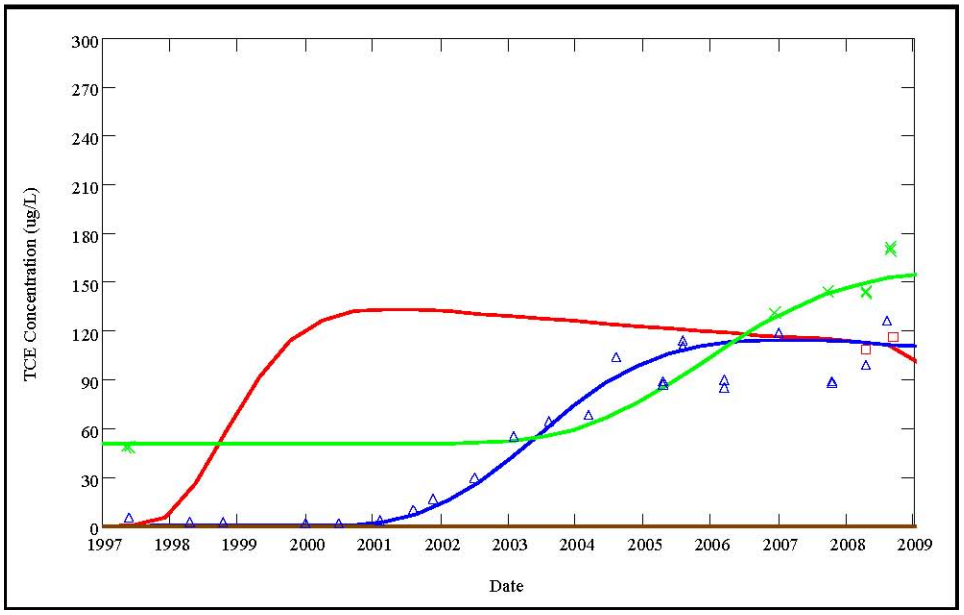
Parameter	TCE	Cr
Mobile/Immobile Porosity Ratio [ ]	0.068	0.068
Transport Velocity, feet per year	308	308
Longitudinal Dispersivity, feet	25	25
Mass Transfer Rate Coefficient, [ ]	120	120
Retardation (due to sorption), [ ]	1	1
Contaminant Half-Life, day	10,000	100,000
Off-Site Source Concentration, µg/L	150	6,000
Off-Site Source Duration, year	11	8
Effective On-going HELSTF Loading Concentration, µg/L	50	600

Notes:

Cr	Chromium
HELSTF	High Energy Laser Systems Test Facility
TCE	trichloroethylene
µg/L	Micrograms per liter

The results of the transport modeling (solid lines) are compared to measured values (points) in the figures below (HMW-61 is represented by red squares, DRW-16 by blue triangles, and DRW-14 by green x's). Although there are significant time-gaps for measured values at the HMW-61 and DRW-14 locations and important model uncertainties and limitations, these results clearly show that the arrival times and concentrations observed at all three wells are very consistent with physically-based model simulation values. This further supports that impacts observed at these wells are attributable to a common off-site source.





To more accurately simulate observations at HMW-14 (located within vadose zone TCE and total chromium impacts at the HELSTF), the model was adjusted to represent minor loading from the HELSTF to the regional aquifer. Specifically, effective concentrations of 50 and 600 µg/L for TCE and total chromium were assumed to be continuously contributed to the regional aquifer from the HELSTF in the HMW-14 area. The actual effective loading concentration and history of these contaminants from the HELSTF is unknown, but this analysis suggests that there is likely some contribution of TCE and total

chromium from the HELSTF, but that this contribution is relatively small compared to the contributions from the up-gradient source.

Conclusions

Several lines of evidence clearly indicate a significant source of TCE, 1,1-DCE, and total chromium upgradient of the HELSTF that is responsible for the all of the TCE and total chromium impacts at HMW-61, DRW-16, and at least a majority of COPC mass at DRW-14. The upgradient source is not fully characterized. For example, additional ~~monitor well~~monitoring wells installed in the regional aquifer north and northwest of the HELSTF area would be needed to further delineate the upgradient source and provide information on potential future source loading. However, existing data provide an adequate understanding of the significance of this upgradient source on groundwater quality beneath the HELSTF.

References

Toride, N., F.J. Leij, and M.Th. van Genuchten. 1993. A comprehensive set of analytical solutions for non-equilibrium solute transport with first order decay and zeroorder production. Water Resources Research, 29:2167-2182.

van Genuchten, M.Th., and R.J. Wagenet. 1989. Two-site/two-region models for pesticide transport and degradation: theoretical development and analytical solutions. Soil Science Society of America Journal, 53:1303-1310.